Nutrient Management for Field Grown Leafy Vegetables – a European Perspective

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THE UNIVERSITY OF WARWICK

Outline of the Talk

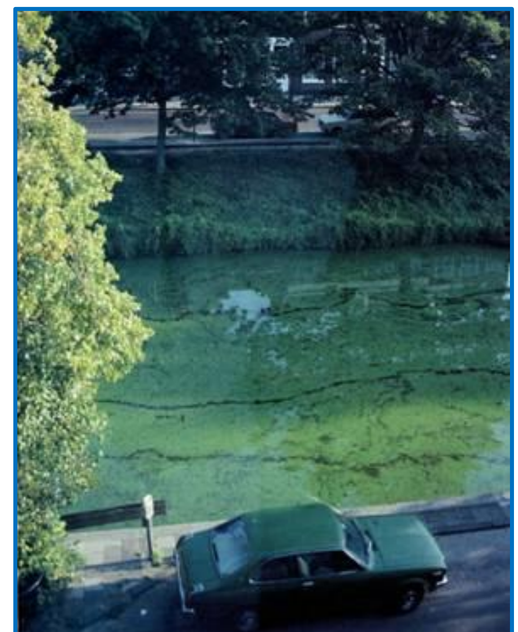
- Background on environmental and food safety regulations
- Nutrient Management Planning for N fertiliser
- Nutrient Management Planning for P, K and Mg fertilisers
- Impacts of the current measures
- Use of more nutrient-efficient fertiliser application techniques
- Potential benefits of growing nutrient-efficient varieties

Background

Intensive agriculture relies heavily on the use of nutrients from fertilisers and manures, but using nutrients inefficiently can result in significant losses to the environment

In the UK, around 60% of the nitrates and 25% of the phosphates in surface waters originate from agricultural land and as much as 90% of the ammonia emissions to the atmosphere are produced from agriculture

The presence of nitrates and phosphates downgrades the quality of natural waters and increases the risk of eutrophication



Control Measures

Nutrient Management aims to minimise these losses by using the smallest amount of nutrient possible to produce the maximum yield of a crop

There are additional regulations to ensure that the food produced is fit for human consumption

Environmental Legislation
The EU Nitrates Directive imposes restrictions on the way farmers use fertilisers and manures to minimise losses of nitrate (and other nutrients) from agricultural land

Food Safety Regulations
Fresh Produce Standards impose restrictions on the types of manure allowed on leafy vegetable crops to reduce the risk of contamination with human pathogens

Key measures within the Nitrates Directive

All EU countries are required

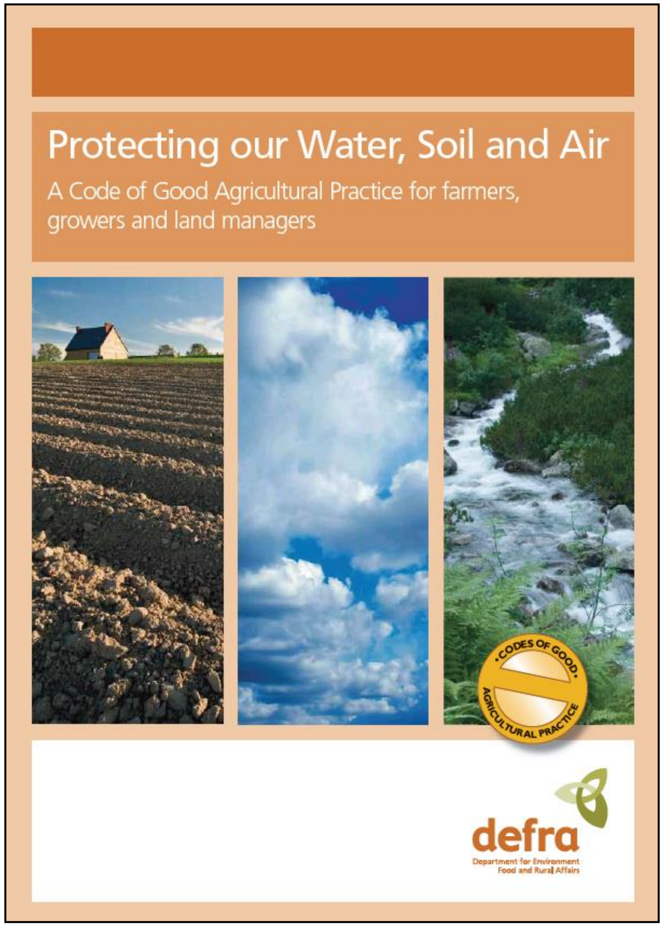
- To identify water already polluted *or at risk of pollution* including any
  - surface waters and groundwater with nitrate concentrations >50 mg/l
  - freshwater bodies, estuaries, coastal waters and marine waters found to be eutrophic
- To designate as Nitrate Vulnerable Zones (NVZs)
  - any area of land which drains into these polluted waters or into waters at risk of pollution
- To set up Codes of Good Agricultural Practice and Action Programmes to help farmers use fertilisers and manures more efficiently
  - especially those with farms in NVZs
- To monitor water quality and update NVZs and Action Programmes every 4 years

Additional Measures in the Nitrates Directive

Each EU country must

Establish Codes of Good Agricultural Practice to encourage farmers to *voluntarily*

- restrict the application of fertilisers and manures in autumn and winter
- restrict the application of fertilisers and manures on sloping land, frozen or snow-covered soil, near water courses, etc
- use rotations, soil winter cover and catch crops to reduce losses of nitrate by leaching and phosphate by soil erosion
- provide adequate storage capacity for livestock manures

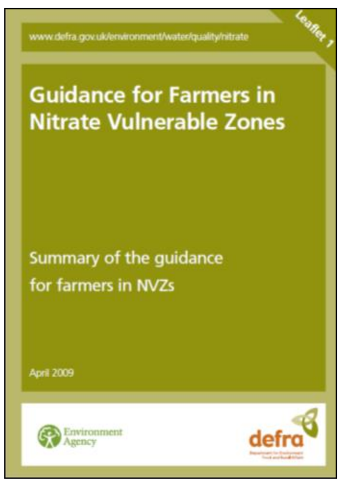


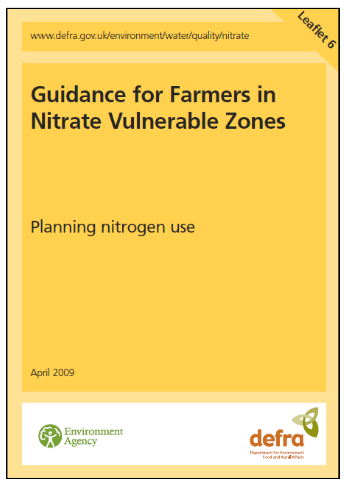
Additional Measures in the Nitrates Directive

Each EU country must

Establish *compulsory* Action Programmes which impose a legal requirement on *all farmers within NVZs*

- to follow the Codes of Good Agricultural Practice
- to adopt Nutrient Management Planning for all crops
- to adhere to maximum limits on annual fertiliser and manure use


Leaflet 1
www.defra.gov.uk/environment/water/quality/nitrate
Guidance for Farmers in Nitrate Vulnerable Zones
Summary of the guidance for farmers in NVZs
April 2009
Environment Agency
defra


Leaflet 6
www.defra.gov.uk/environment/water/quality/nitrate
Guidance for Farmers in Nitrate Vulnerable Zones
Planning nitrogen use
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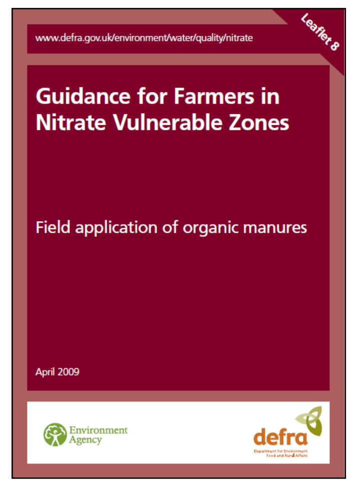
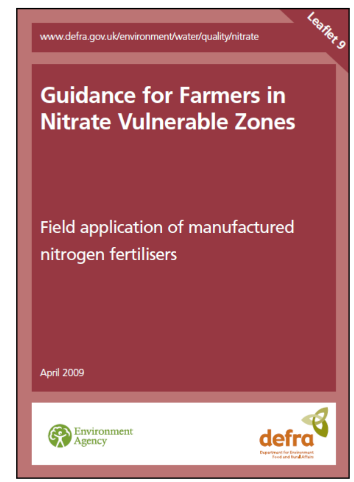
Environment Agency
defra


Leaflet 8
www.defra.gov.uk/environment/water/quality/nitrate
Guidance for Farmers in Nitrate Vulnerable Zones
Field application of organic manures
April 2009
Environment Agency
defra


Leaflet 9
www.defra.gov.uk/environment/water/quality/nitrate
Guidance for Farmers in Nitrate Vulnerable Zones
Field application of manufactured nitrogen fertilisers
April 2009
Environment Agency
defra

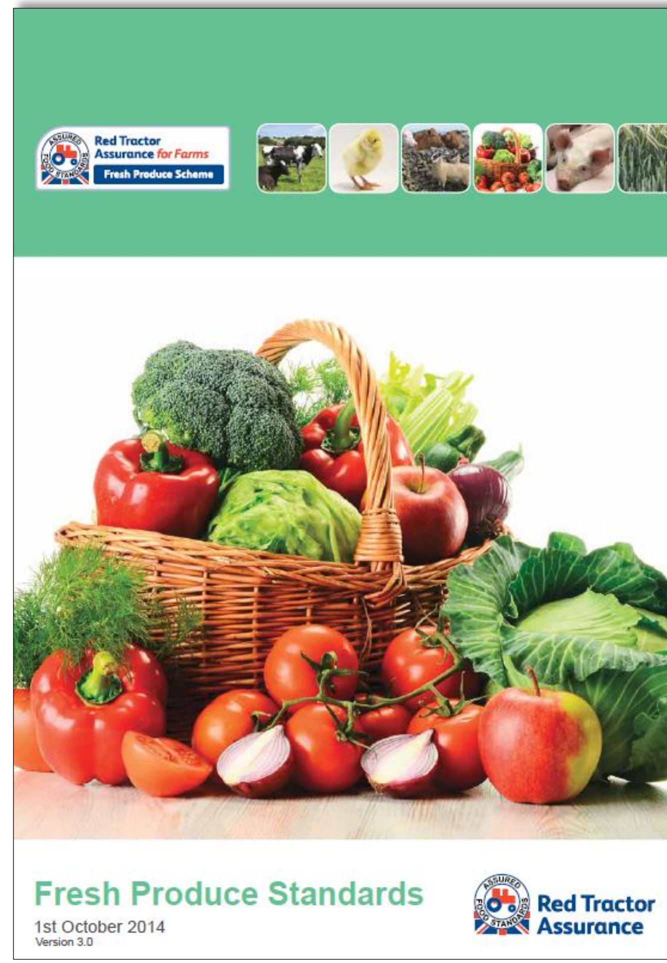
There are 9 different leaflets summarising the regulations and farmers can download these from Government websites, together with information on the latest changes to help them follow the rules

Additional Food Safety Restrictions

Fresh Produce Standards ban the use of most organic manures on vegetable soils for up to 30 months before the crop is harvested

- especially for raw leafy salad crops (lettuce, rocket, spinach, celery) and brassica (cabbage, Chinese cabbage, etc)

The only exceptions are certified green waste composts and pasteurised digestates, both of which have little nutrient value



As a result, virtually no organic manures are used to fertilise leafy vegetable crops grown in intensive production

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Nutrient Management for Nitrogen Fertiliser

This is based on a simple nutrient balance equation where all units are in kg N/ha

Nitrogen Fertiliser needed = Crop Nitrogen requirement - Soil Nitrogen supply

Nitrogen fertiliser needed includes N from manufactured fertiliser (and from any organic manures applied at any time after harvesting the previous crop)

Crop requirement is the amount of Nitrogen which must be applied to produce the economic maximum yield

- estimated from historical response data for each crop

Soil Nitrogen Supply consists of

- mineral Nitrogen present in the top 90 cm of soil
- Nitrogen expected to be mineralised during the growth of the crop

The *Soil Nitrogen Supply can be* estimated either by direct measurement or by using a Field Assessment Method

Assessing the Soil Nitrogen Supply

Method 1: Soil Measurement

Step 1

Sample the soil to 90 cm as close as possible to the time of N fertiliser application
- usually just before planting a crop

At least 15 soil cores are needed for areas of up to 20 ha with the same cropping history, provided the soil is uniform

Step 2

Refrigerate samples and send away for immediate analysis of soil mineral N content

Step 3

Convert the result into kg N/ha for the top 90 cm of soil, then add an estimate for N mineralised during subsequent growth from tables of data for different crops

Assessing the Soil Nitrogen Supply

Method 2: Field Assessment

Step 1

This uses tables of information on

- recent cropping history to estimate the amount of residual N remaining in the soil in the previous autumn
- soil type and typical winter rainfall to adjust this residual N for nitrate lost by leaching to estimate the amount of soil mineral N present in spring

Step 2

The Soil Nitrogen Supply for the new crop is then calculated by adding a figure for the amount of N likely to be mineralised during its growth

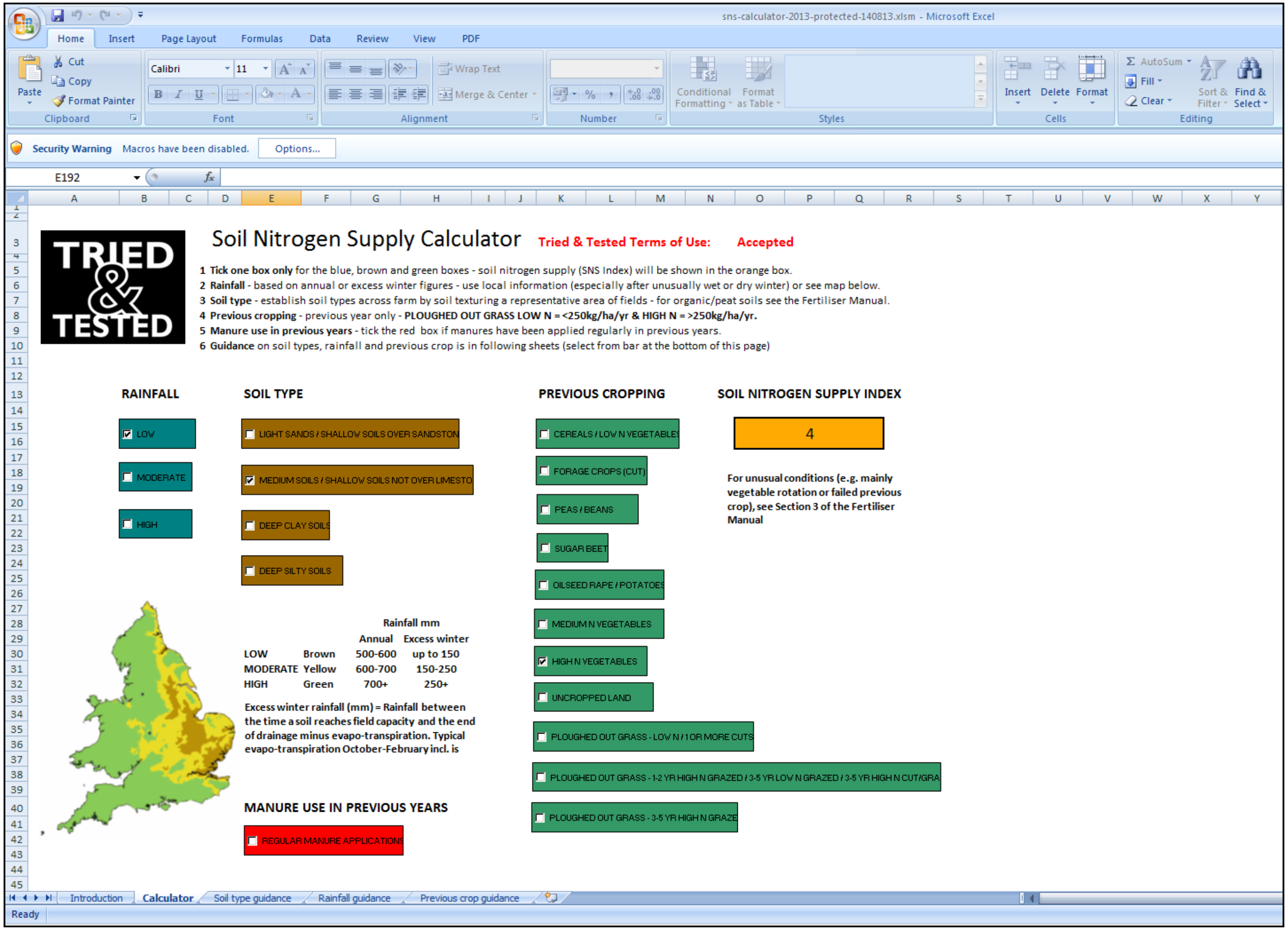
Step 3

Final adjustments can be made where large amounts of leafy crop residues or manures have regularly been incorporated in previous years

- or where grassland has been ploughed in during the last 2-3 years

Soil Nitrogen Supply Calculator

An Excel worksheet is available to do the calculations for the Field Assessment Method



UK Agricultural Industries Confederation (2013)

Obtaining a Nitrogen Fertiliser Recommendation

Once the Soil Nitrogen Supply has been estimated, a provisional recommendation for the amount of N fertiliser required is read off from a table of data for each crop

Provided this recommendation does not exceed maximum (N max) limits set in the Action Programme under the EU Nitrates Directive, then this amount may be applied

Crop	N max limit (kg N/ha)
Group 1	
Asparagus, carrots, radishes, swedes, individually or in any combination	180
Group 2	
Celery, courgettes, dwarf beans, lettuce, onions, parsnips, runner beans, sweetcorn, turnips individually or in any combination	280
Group 3	
Beetroot, brussels sprouts, cabbage, calabrese, cauliflower, leeks individually or in any combination	370

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Nutrient Management for P, K and Mg Fertilisers

Background

Concentrations of P, K and Mg in soil change only slowly from one year to the next

Maximum yields of arable and vegetable crops can normally be obtained if the concentrations of P, K and Mg in the top 15 cm of soil are in a narrow target range just above a critical level for each nutrient

Principle of the Method

Adopt one of three management strategies depending on the nutrient status of the soil

For soils already within the target range

- apply a maintenance dressing of P, K or Mg to replace nutrients removed by next crop and maintain the soil in the target range

For soils below target range

- apply additional fertiliser to raise the soil status gradually over several years

For soils above target range

- apply less fertiliser (or none at all) to reduce nutrient levels gradually over time

Nutrient Management for P, K and Mg fertilisers

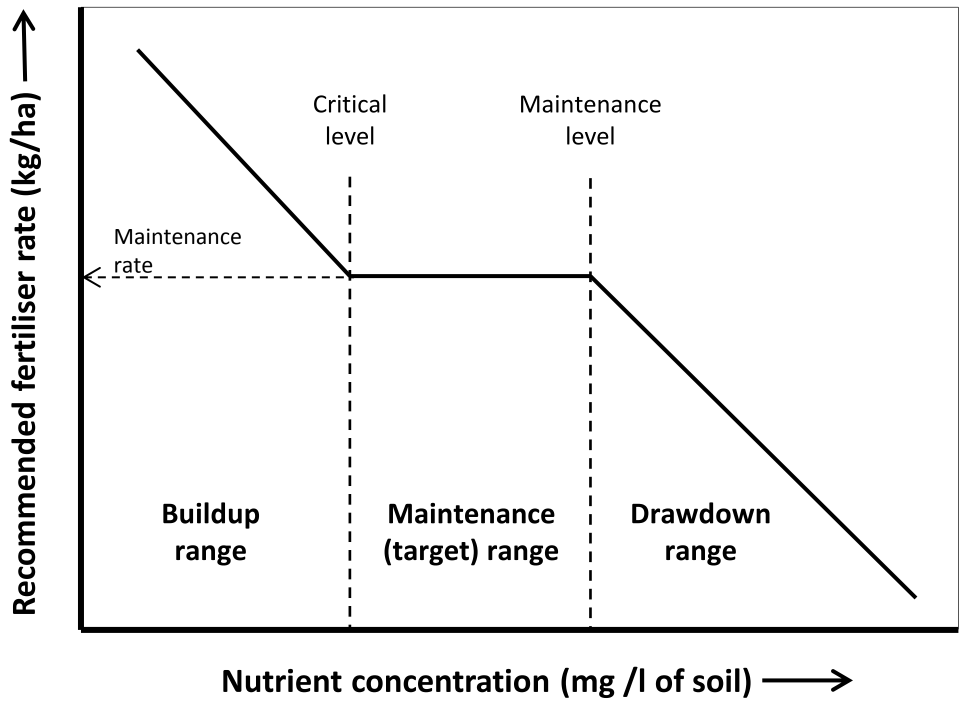
Target Ranges for P, K and Mg in Top 15 cm Soil

Crop type	Soil P	Soil K	Soil Mg
	mg/l of soil*		
Arable and forage crops	16-25	120-180	26-50
Vegetables and potatoes	26-45	181-240	51-100

* Soil analysis - P measured on $NaHCO_3$ extracts (as Olsen P)
- exchangeable K and Mg measured on NH_4NO_3 extracts

Note - the critical levels are greater for shallow rooting vegetable and potato crops because they are less efficient at exploiting the subsoil

Nutrient Management for P, K and Mg fertilisers



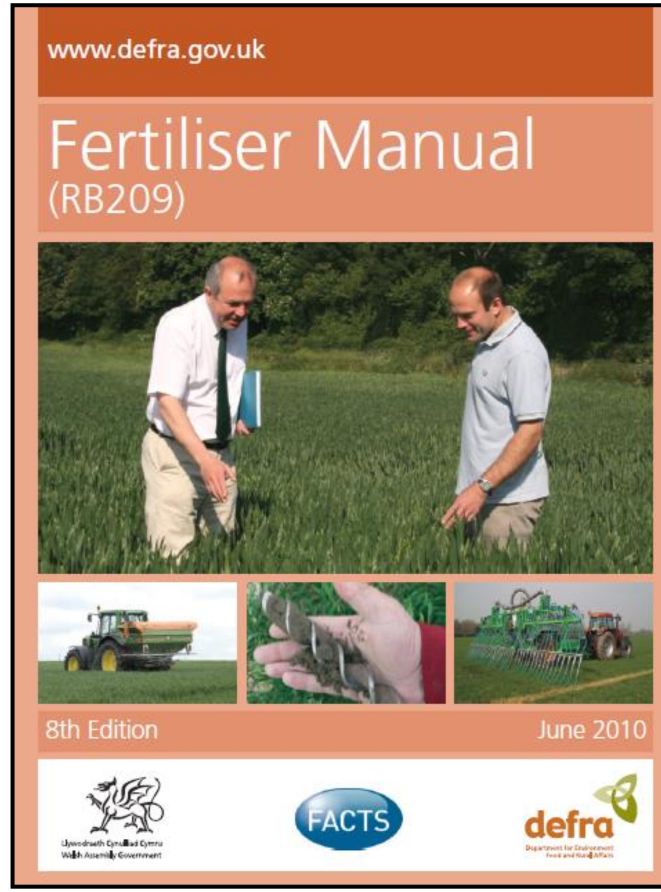
Recommendations

Tables of recommendations are provided for all important arable and vegetable crops

- the recommended fertiliser rates vary with P, K or Mg status where the soil is in either the buildup or drawdown range

The Fertiliser Manual

provides tables of recommendations for all major arable and vegetable crops in the United Kingdom
- based on the estimated N, P, K or Mg status of the soil



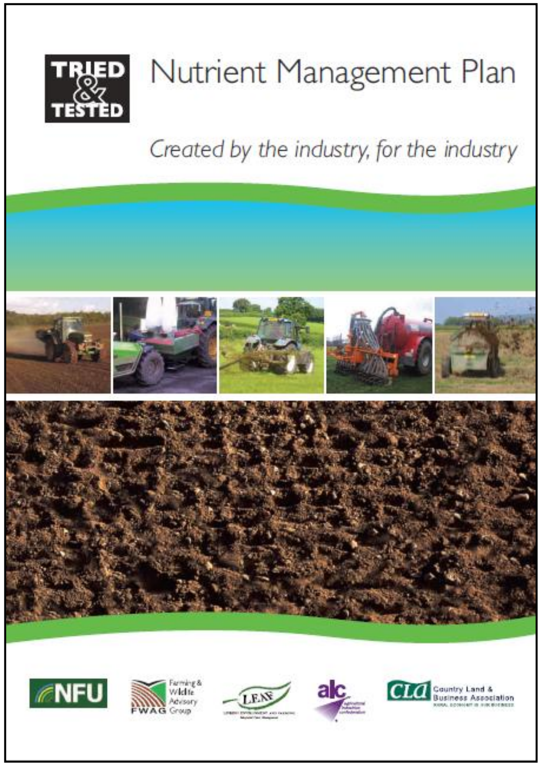
PLANET

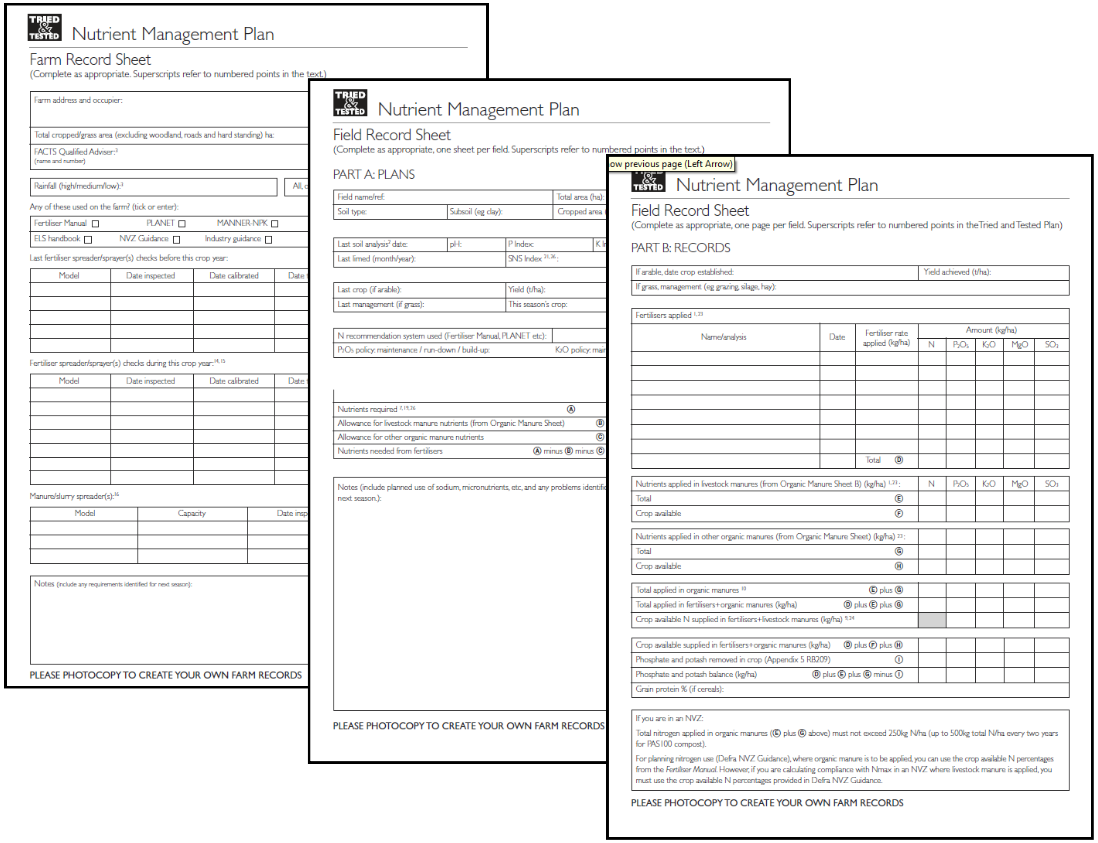
NUTRIENT MANAGEMENT

Planning **L**and **A**pplication of **N**utrients for **E**fficiency and the Environmen**T**

and a version is also available as a computer Decision Support System

Nutrient Management Planning




TRIED & TESTED Nutrient Management Plan

Farm Record Sheet

(Complete as appropriate. Superscripts refer to numbered points in the text.)

Farm address and occupier:

Total cropped/grass area (excluding woodland, roads and hard standing) ha:

FACTS Qualified Adviser:

Rainfall (high/medium/low):

Any of these used on the farm? (tick or enter):

Fertiliser Manual ☐ PLANET ☐ MANNER-NPK ☐

ELS handbook ☐ NVZ Guidance ☐ Industry guidance ☐

Last fertiliser spreader/sprayer(s) checks before this crop year:

Model	Date inspected	Date calibrated

Fertiliser spreader/sprayer(s) checks during this crop year:

Model	Date inspected	Date calibrated

Manure/slurry spreader(s):

Model	Capacity

Notes (include any requirements identified for next season):

PLEASE PHOTOCOPY TO CREATE YOUR OWN FARM RECORDS

TRIED & TESTED Nutrient Management Plan

Field Record Sheet

(Complete as appropriate, one sheet per field. Superscripts refer to numbered points in the text.)

PART A: PLANS

Field name/ref: Total area (ha):

Soil type: Subsoil (eg clay): Cropped area

Last soil analysis date: pH: P Index:

Last limed (month/year): SNS Index

Last crop (if arable): Yield (t/ha):

Last management (if grass): This season's crop:

N recommendation system used (Fertiliser Manual, PLANET etc):

P₂O₅ policy: maintenance / run-down / build-up: K₂O policy:

Nutrients required Ⓐ

Allowance for livestock manure nutrients (from Organic Manure Sheet) Ⓑ

Allowance for other organic manure nutrients Ⓒ

Nutrients needed from fertilisers Ⓐ minus Ⓑ minus Ⓒ

Notes (include planned use of sodium, micronutrients, etc, and any problems identified for next season):

PLEASE PHOTOCOPY TO CREATE YOUR OWN FARM RECORDS

TRIED & TESTED Nutrient Management Plan

Field Record Sheet

(Complete as appropriate, one page per field. Superscripts refer to numbered points in the Tried and Tested Plan)

PART B: RECORDS

If arable, date crop established: Yield achieved (t/ha):

If grass, management (eg grazing, silage, hay):

Fertilisers applied

Name/analysis	Date	Fertiliser rate applied (kg/ha)	N	P_2O_5	K_2O	MgO	SO_3
		Total Ⓓ					

	N	P_2O_5	K_2O	MgO	SO_3
Nutrients applied in livestock manures (from Organic Manure Sheet B) (kg/ha)					
Total Ⓔ					
Crop available Ⓕ					
Nutrients applied in other organic manures (from Organic Manure Sheet) (kg/ha)					
Total Ⓖ					
Crop available Ⓗ					
Total applied in organic manures Ⓔ plus Ⓖ					
Total applied in fertilisers+organic manures (kg/ha) Ⓓ plus Ⓔ plus Ⓖ					
Crop available N supplied in fertilisers+livestock manures (kg/ha)					
Crop available supplied in fertilisers+organic manures (kg/ha) Ⓓ plus Ⓕ plus Ⓗ					
Phosphate and potash removed in crop (Appendix 5 RB209) Ⓘ					
Phosphate and potash balance (kg/ha) Ⓓ plus Ⓔ plus Ⓖ minus Ⓘ					
Grain protein % (if cereals):					

If you are in an NVZ:

Total nitrogen applied in organic manures (Ⓔ plus Ⓖ above) must not exceed 250kg N/ha (up to 500kg total N/ha every two years for PAS100 compost).

For planning nitrogen use (Defra NVZ Guidance), where organic manure is to be applied, you can use the crop available N percentages from the *Fertiliser Manual*. However, if you are calculating compliance with Nmax in an NVZ where livestock manure is applied, you must use the crop available N percentages provided in Defra NVZ Guidance.

PLEASE PHOTOCOPY TO CREATE YOUR OWN FARM RECORDS

Accurate record keeping is essential to demonstrate compliance with the Nitrates Directive, and guidelines on the records needed are available from various websites

- together with templates for entering the data

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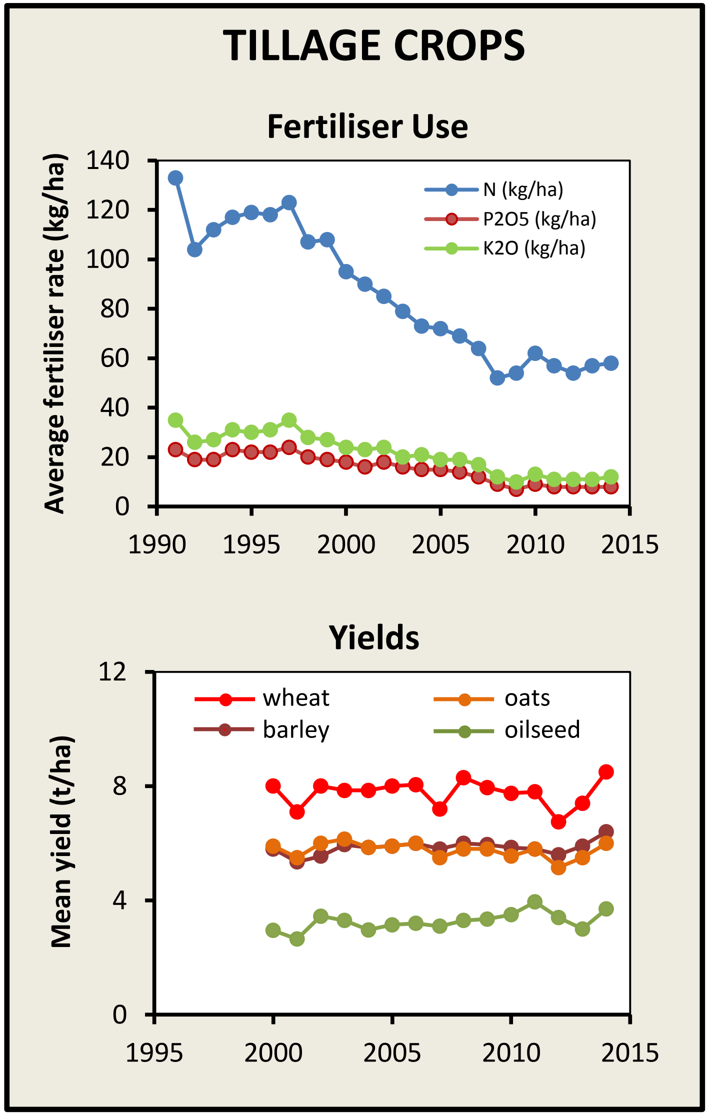
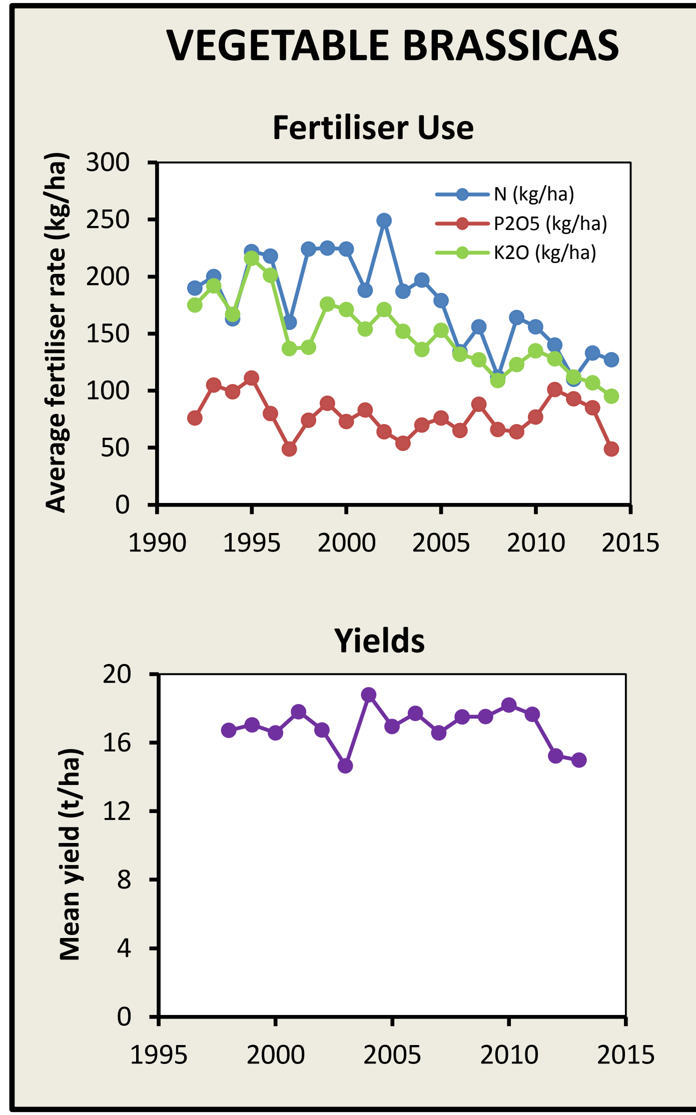
Effects on Fertiliser Use and Crop Yields

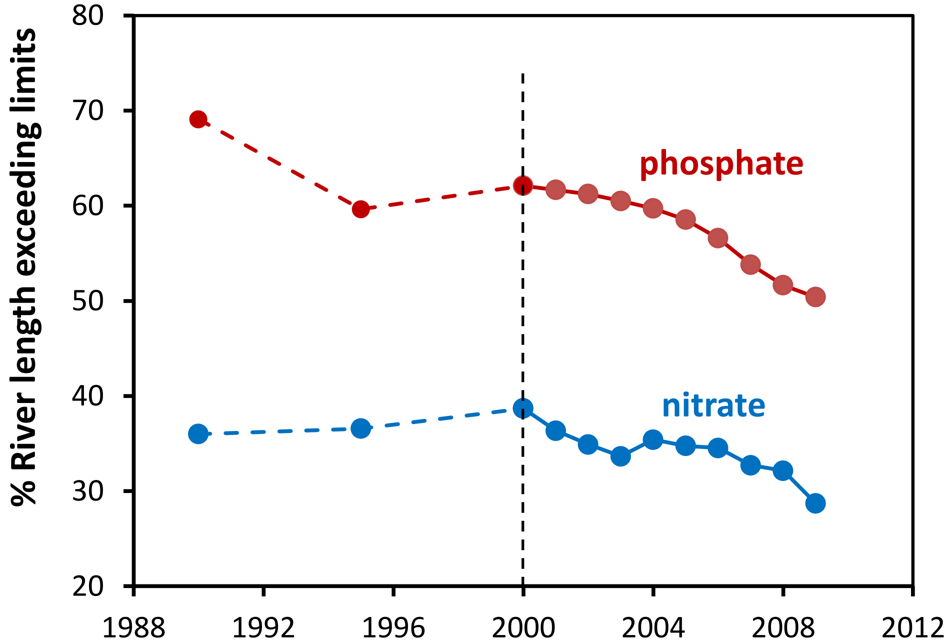




Average fertiliser rates declined from around 1998, but did not reduce yields

Effects on River Quality

Since 2000 there has been a gradual decline in the total length of rivers
- with nitrate concentrations > 30 mg/l
- with phosphate concentrations > 0.1 mg P/l



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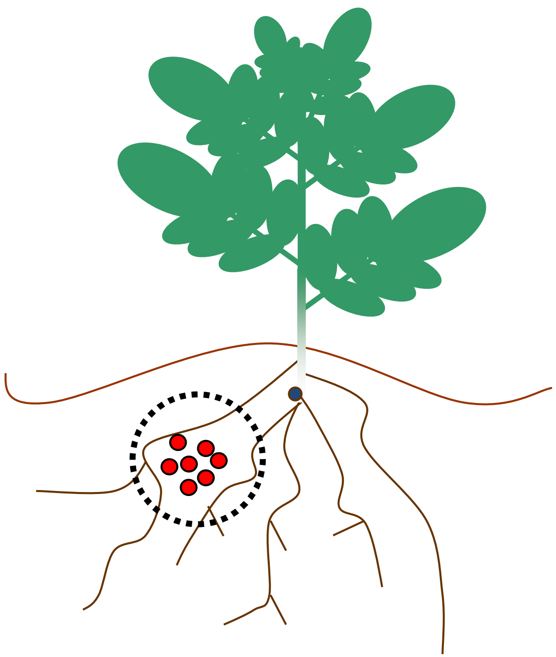
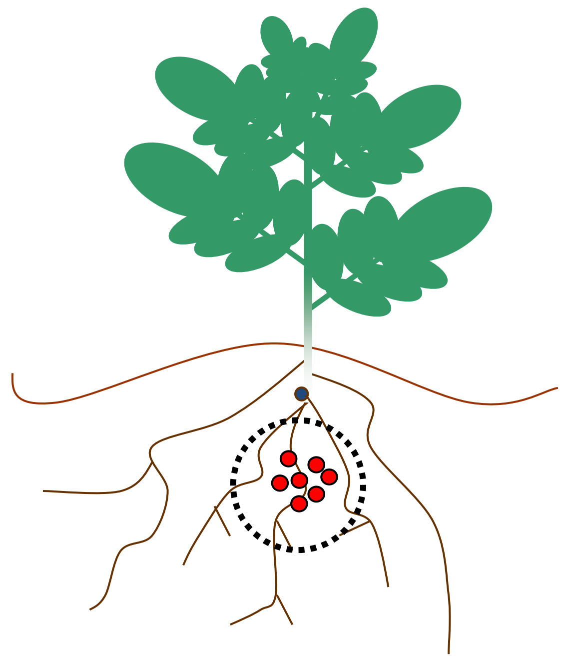
Fertiliser Placement for Greater Efficiency

Fertiliser can be placed to the side



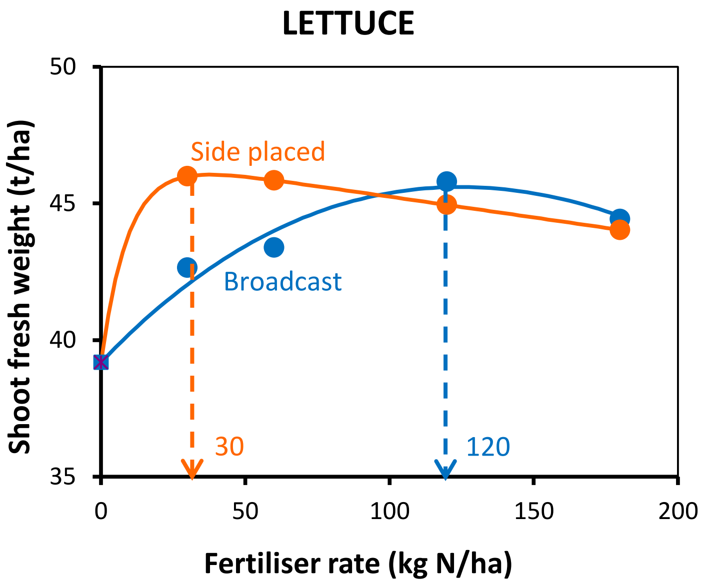
or below the seed row



close enough for the nutrients to be readily available without damaging the developing seedling

Side Injection of Urea Ammonium Nitrate on Field-grown Lettuce

Spoke wheel injectors can 'spot' liquid fertilisers into the soil between the crop rows



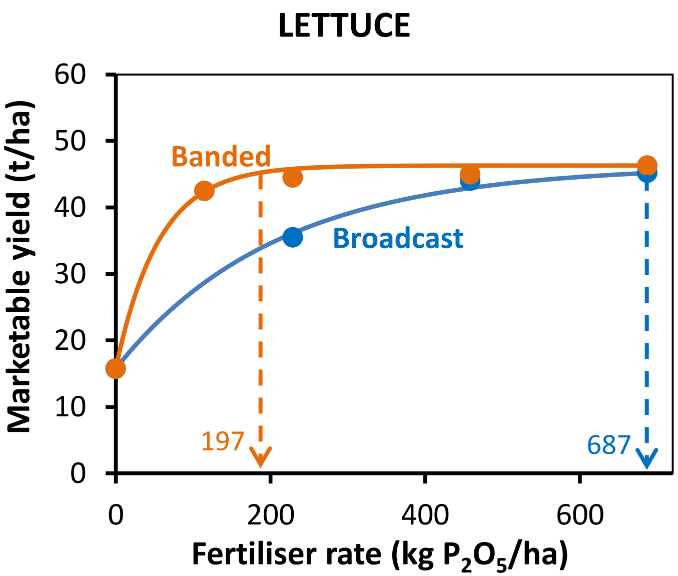
Side injection of liquid fertiliser can give the same maximum yield from smaller amounts of applied N than from broadcast applications of granular fertiliser

after Stone (2000)

In-row Banding of Triple Superphosphate on Field-grown Lettuce

Solid fertilisers can be pumped into the soil through tines positioned

- either within the drill line
- or between the rows



Granular fertiliser applied as an in-row band can give the same maximum yield from a smaller amount of total P compared with a broadcast application

after Sanchez et al (1990)

Plant Weights from Placed Triple Superphosphate at Half the Rate of Broadcast Applications

Crop	Broadcast at Recommended Rate	Side placed at 50% of Recommended Rate	Crop weight ratio (Placed / Broadcast)
Potato tubers (kg / plot)	18.3 ± 0.7	18.9 ± 1.1	1.03
Salad onions (g / plant)	16.3 ± 1.2	18.7 ± 1.2	1.14
Carrot roots (g / plant)	56.6 ± 5.5	70.0 ± 6.2	1.24
Cabbage hearts (g / plant)	185 ± 11	178 ± 11	0.96
Lettuce heads (g / plant)	533 ± 43	546 ± 28	1.02

Means ± SE, n = 6 (potato), n = 3 (other crops)

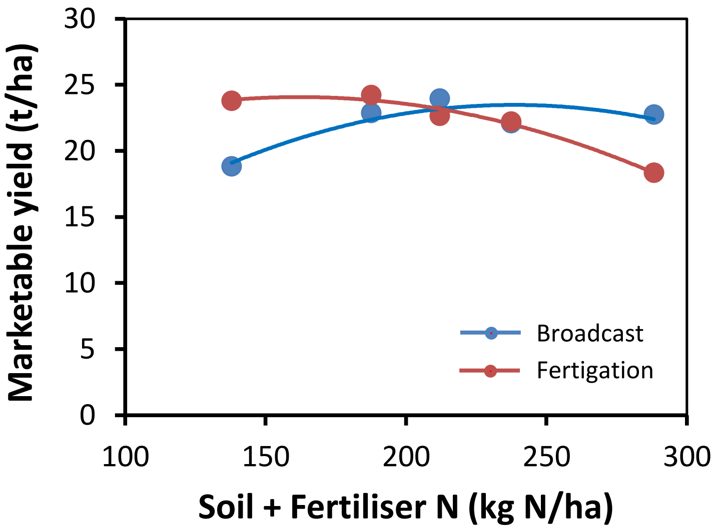
Increased P use efficiency from banded applications of triple superphosphate can give equivalent yields with as little as half the amount of broadcast fertiliser

after Burns et al (2010)

Fertigation of Field-grown Lettuce

Young lettuce crop

Application of Fertiliser through a drip irrigation system



Fertigation can give the same maximum yield from smaller amounts of applied N than broadcast applications of granular fertiliser given the same amount of irrigation

after Monaghan et al (2010)

Benefits of Placed Fertiliser

- boosts early growth of many different vegetable crops
- increases the final yield of some crops
- produces the same yield of all crops with less fertiliser
- can advance maturity date and improve crop quality
- increases the efficiency of nutrient use
- reduces the risk of environmental impacts
- may need nutrients from supplementary dressings to maximise benefits

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Selecting Cultivars with Greater Nutrient Efficiency

Comparison of Nitrogen Efficiency in 96 F_7 Recombinant Inbred Lines of Lettuce

Plants grown under poly tunnels in the field

Efficiency factors:

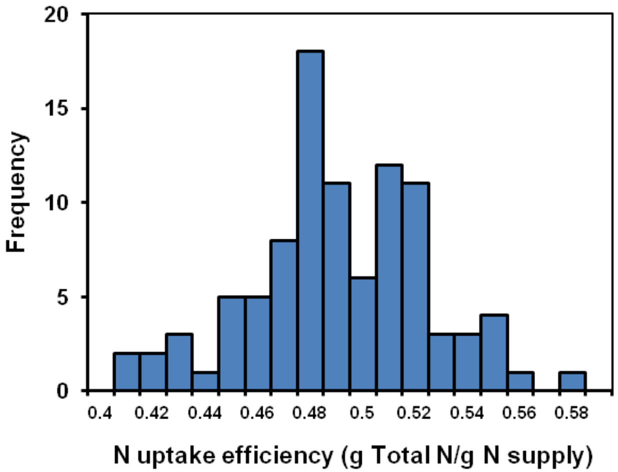
$$\text{N Uptake Efficiency} = \frac{\text{Tissue N (g)}}{\text{N supply (g)}}$$

$$\text{N Utilisation Efficiency} = \frac{\text{DWt (g)}}{\text{Tissue N (g)}}$$

$$\text{N Use Efficiency} = \frac{\text{DWt (g)}}{\text{N supply (g)}}$$

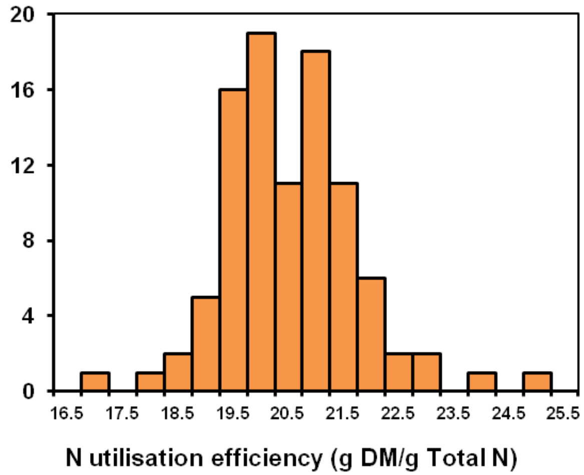
Nitrogen Uptake and Utilisation Efficiency Factors for Lettuce - Frequency Distributions for 96 F_7 Recombinant Inbred Lines

Nitrogen Uptake Efficiency



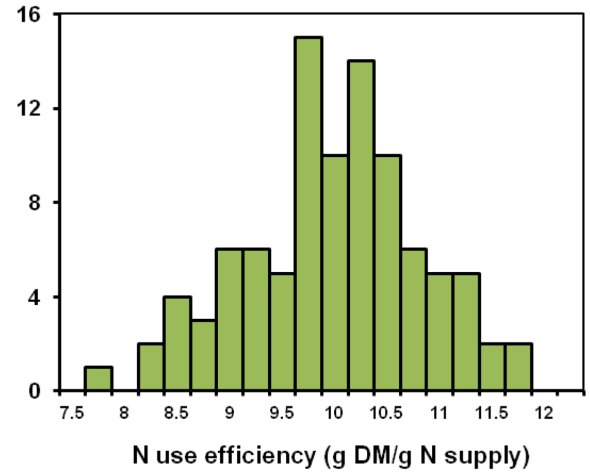
Range 36.3 % of mean

Nitrogen Utilisation Efficiency



Range 39.3 % of mean

Nitrogen Use Efficiency

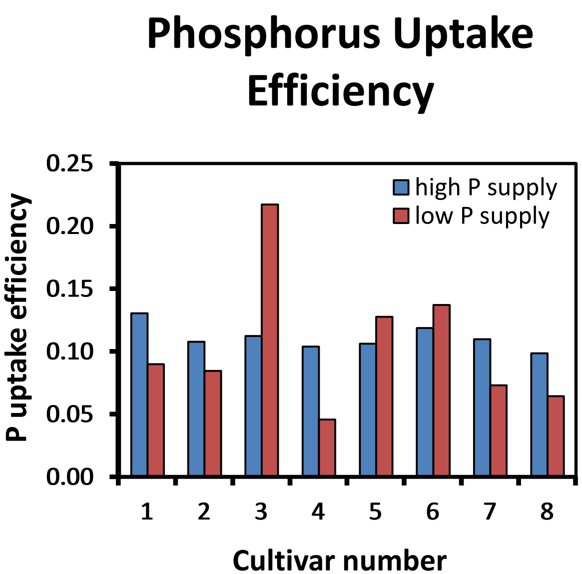


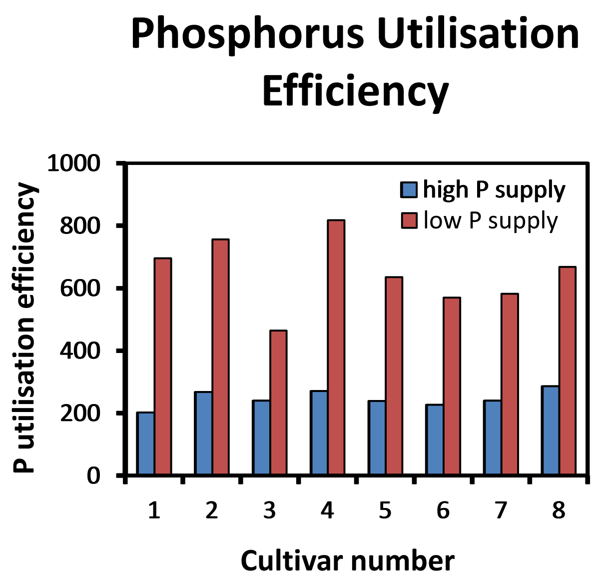
Range 40.5 % of mean

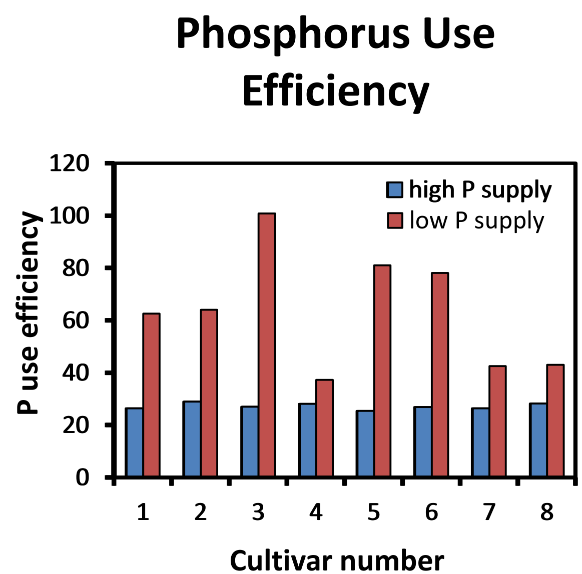
Conclusion: There was significant inherent genetic variation in nutrient efficiency within this population when the plants were grown with an adequate N supply, even though all lines were derived from just two cultivars used in the original cross

after Burns et al (2012)

Phosphorus Uptake and Utilisation Efficiency Factors for Cabbage Varieties







Conclusion: There was a small amount of inherent genetic variation in nutrient efficiency between these varieties when grown with an adequate P supply

- but this variability became much greater when the P supply was reduced

after Eticha and Schenk (2001)

Summary - 1

- Nutrient Management Planning in Europe has been developed within a strict legal framework designed to protect the quality of both surface waters and groundwater
- Farmers in Nitrate Vulnerable Zones are obliged by law to adopt these new methods, and Member States within the European Union must provide detailed guidelines and support to help them follow the rules
- Nutrient Management for N fertiliser is based on the principle of precisely ‘tailoring’ the N supply to the requirement of the crop
- Nutrient Management for P, K and Mg fertilisers is aimed at fertilising the soil to maintain the levels of these nutrients in the optimum range for crop growth

Summary - 2

- Statistical data suggest these measures are
  - reducing overall rates of fertiliser use without detriment to crop yields
  - reducing the concentrations of nitrate and phosphate in surface waters

- Currently Nutrient Management Methods have focussed largely on improving the use of conventional broadcast applications of fertiliser, and attention must now turn to encouraging farmers to exploit the latest application methods to make further improvements to nutrient efficiency

- In the future further research is needed on studies of the genetic variation in nutrient efficiency of vegetable crops to allow farmers to select the most nutrient-efficient varieties that will require less fertiliser to produce optimum yields

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